Delineation and Sampling of the Spill Area

AM-1

It is important to mark the spill area so that its boundaries can be located at a later date, especially if the site is snow covered. Airborne Forward-Looking Infrared (FLIR) photography can be used to identify the spill area even if the site is snow covered (Fig. 123). Delineation should begin as soon as possible after the spill has been contained. Correct the boundary location as needed. The contrast between clean and contaminated snow is especially useful for visually delineating affected areas. Even relatively clear fluids such as diesel, methanol, and produced water, can cause dramatic changes in the color and physical characteristics of snow.

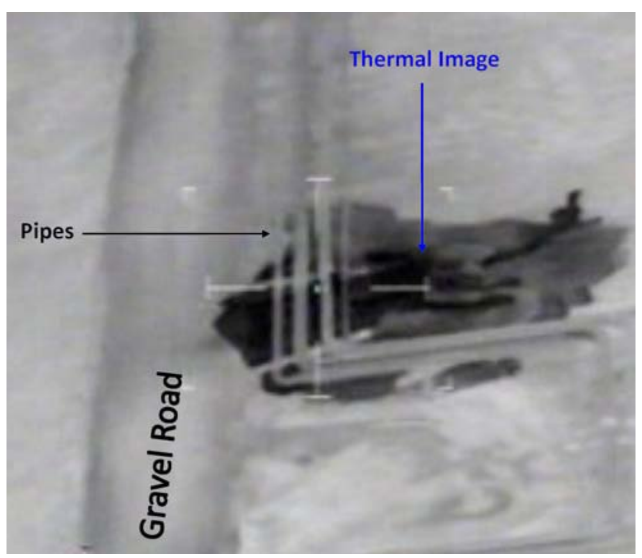

Figure 123. FLIR image of spill area

To delineate large spill areas (>1,000 square feet), two workers walk the perimeter of the spill in opposite directions from a common starting point, and place markers every 50 to 100 feet to provide a visible boundary. The two workers should meet midway around the perimeter of the spill area, and then retrace each other's routes to confirm the delineation. While walking, they look for visible impacts, including spilled substance on the ground; discoloration of plants or soil; sheen on standing water or foliage; and dead or damaged vegetation. For smaller spills, a single worker may perform the delineation. Aerial photographs are of great value for identifying and mapping site features and spill boundaries.

A scaled map of the site probably will be required for planning, monitoring, and reporting purposes and will be most useful if prepared using professional surveying methods (Figs. 124–125). As soon as practical after containment, a sampling system should be implemented, to be used for monitoring (Tactics AM-2 and AM-4). The preferred method is systematic sampling at nodes on a grid system, which facilitates the unbiased selection of sampling locations (Fig. 126). Depending on the shape of the affected area, the grid should be a square or rectangle that is large enough to encompass the containment area and some adjacent unaffected (reference) tundra. Vegetation monitoring plots should be located at the same locations where samples were collected.

For affected tundra areas that are ~0.5 acre (~150′ x 150′) in size, a grid with 15-ft spacing would create 100 nodes where lines intersect. Typically, samples are collected at a subset of nodes, chosen using an unbiased selection method. This approach can be used for a site of any size simply by expanding the grid.

For larger sites (> 1 acre), the distance between nodes can be changed to create a reasonable number of potential sampling locations, or to meet specific sampling objectives. For example, the spill area may be subdivided into areas with high, medium, and low concentrations of contaminants (Fig. 127). If the sampling plan stipulates that 10 samples should be collected from each area, the size of the grid can be adjusted to provide at least 10 potential sampling locations in each area. When the affected tundra includes patterned ground, the grid distances should be less than the average polygon diameter to avoid sampling bias among topographical features (e.g., polygon centers, rims, and troughs).

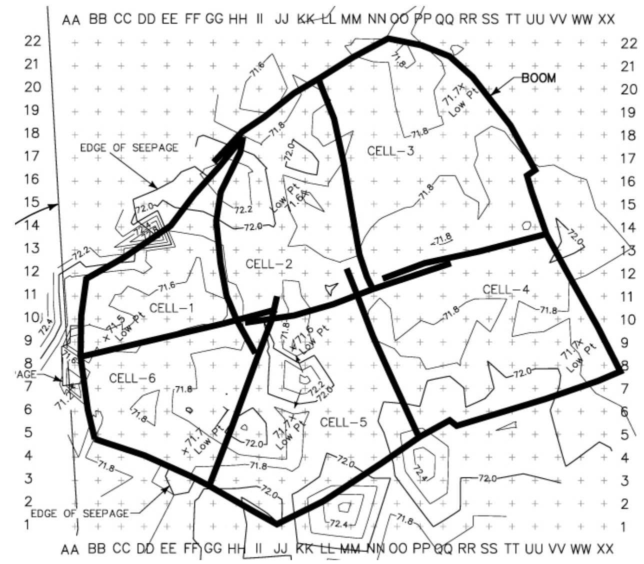

Figure 124. Sampling grid and elevation contours

Two methods exist for establishing the grid system at a site. Importantly, neither method interferes with cleanup operations, because permanent stakes or markers are not needed to locate sampling stations within the spill area. Nevertheless, sample stations can be relocated with good precision. The first method uses permanent markers (e.g., survey nails, wooden stakes, or rebar) that are driven into the ground in two parallel rows on opposite sides of the spill, and that are separated by the appropriate distance between grid nodes. Each marker is labeled with a row number (e.g., 1 through 10), letter (e.g., A, B, C), or distance from a corner of the grid (e.g., 0, 2, 4, 6 for a 2-ft grid). Individual sampling points are then located by stretching a tape between the corresponding end stakes and sampling is done at specified distances along the tape. The second method uses a "virtual grid" created with computer software (e.g., AutoCAD). The coordinates of selected sample stations are then uploaded to a field computer, which is used to navigate to the sample location (Fig. 128). The use of a virtual grid generally requires contracting the services of a professional surveyor, although other personnel with special training and equipment can also establish a virtual grid.

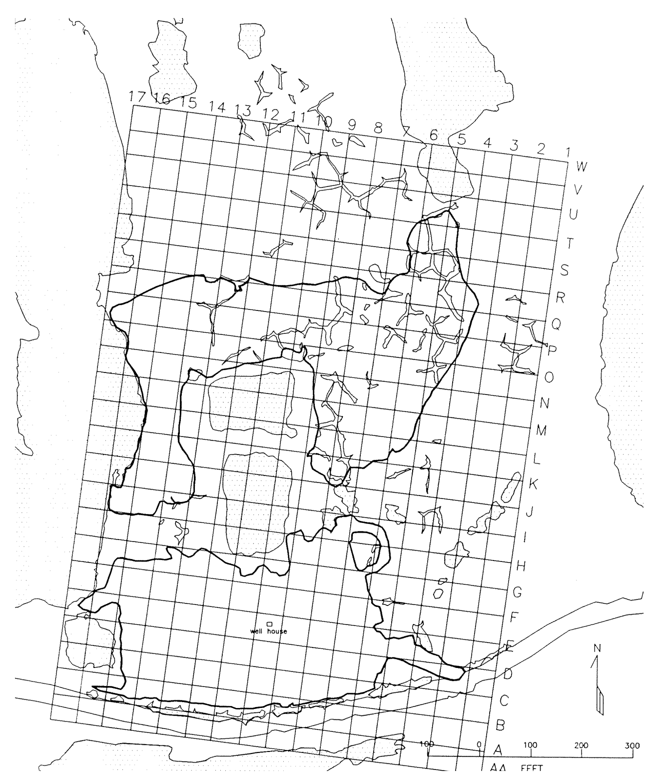

Figure 125. Sampling grid

Figure 126. Wooden lathe showing sampling locations on grid

—Continued

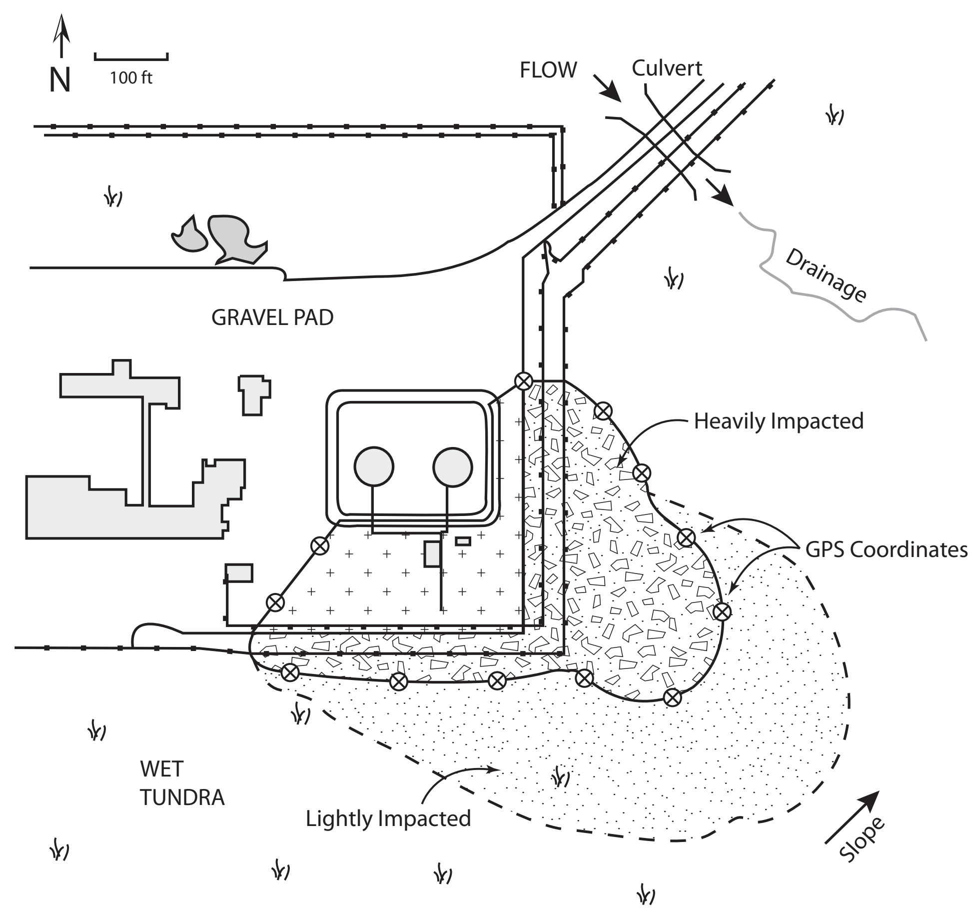

Figure 127. Typical site layout

Figure 128. Marking sampling locations

A variety of maps probably will be needed and should include at least the following elements:

- Location of the spill source.
- Boundary of the affected area.
- Areas of low and high concentration of spilled substance.
- Adjacent roads and structures.
- Tundra types within affected area.
- Sensitive areas and habitats (identification may require special training or additional work).
- Nearby drainages or water bodies, most likely direction of water movement, location of culverts in road.
- Slope and topography (e.g., elevation contours).
- Location of monument used to control survey locations and elevations.
- Sampling grid that can be overlaid on the site map.
- Sampling locations (including background samples), preferably at nodes on sampling grid.
- Vegetation study plots, transects, or photo-plot locations (include direction of photo).
- North arrow, scale and approximate latitude and longitude of the site.

Considerations and Limitations

- Technical literature (e.g., www.EPA.gov) is available to help design a plan for sampling and data collection.
- The area of an uncontained spill will expand with time on all types of tundra.
- The boundaries of spills of saline or water-soluble substances are difficult to delineate visually, especially when snow is absent. These spills tend to spread rapidly except in winter, when the fluids mix with snow and freeze. If salts or other water-soluble compounds are present in high enough concentrations, the vegetation may die or show signs of stress (wilting, discoloration, loss of foliage) in affected areas.
- Seasonal frost action in the soil may push wooden stakes out of the ground over time (i.e., frost-jacking). Wooden stakes may also be disturbed by winter vehicle traffic in the area. Metal rebar may pose a physical hazard. Survey pins (e.g., 9-inch nails) with bristles are preferred because they do not pose a safety hazard, they are less affected by frost-jacking, and they can be relocated with a metal detector.
- Plywood boardwalks may be needed to protect tundra from trampling.
- Considerations for site assessments used by the Alaska Department of Environmental Conservation are found in 18 AAC 78.090.
- This tactic has been adapted from Tactics T-1 and T-2 in the *Alaska Clean Seas Technical Manual* (http://www.alaskacleanseas.org/techmanual.htm).

Equipment, Materials, and Personnel

- *Permanent markers* (9-inch nails or wooden lath stakes) (1 or 2 workers) – to mark spill perimeter and grid system.
- *Handheld GPS unit* (1 operator) – to provide coordinates for initial site delineation.
- *Professional survey equipment and personnel* (variable) – to permanently mark grid layout, sampling locations, and to provide a scaled drawing.

Field Indicators AM-2

Field indicators are standardized, simple measurements or qualitative observations that can be made periodically at a site to monitor and document contamination, treatment effectiveness, and ecological damage associated with the cleanup operation. Field indicators also provide a context for interpreting chemical analyses of soil samples (Tactic AM-4 and Tactic AM-5) and data on vegetation response (Tactic AM-6). Field indicators are important components of a baseline site assessment or monitoring program.

Four categories of field indicators may be measured or observed:

- ***Spill Residue***: Treatment progress may be monitored by visually assessing the degree of contamination on soil and vegetation (Table 7).
- ***Soil Conditions***: The rooting zone, where contamination is most harmful to plants, usually extends 1 to 8 inches (2 to 20 centimeters) below the ground surface. Evaluating the infiltration of contaminants into this zone provides a helpful indicator of how vegetation is likely to respond (Table 8).
- ***Ecological or Physical Damage***: Cleanup operations can result in physical damage with long-term ecological consequences, including thawing of permafrost (thermokarst). Monitoring physical damage can help determine the point at which intensive treatment should stop. The thickness of the active layer (thaw depth) should be measured periodically, so that thermokarst can be monitored over time (Table 9).
- ***Ecological recovery***: Recovery at a site is indicated by growth of native plants and re-establishment of drainages, and a stable thermal regime typical of permafrost terrain.

Measure and observe field indicators at pre-established sampling points, preferably at discreet points on a sampling grid. The number and locations of sampling points should be established by agreement between the responsible party and regulatory agencies. Field sampling points should represent the entire site, with no bias to either heavily or lightly impacted areas. The number of sampling points that are needed will depend on the degree of contamination and the size of the affected area. A small site with heavy contamination may require a relatively intensive sampling approach (e.g., 10 field sampling points per 0.1 acres). For larger sites, spread field sampling points out more widely to characterize the entire site (e.g., 1 sample per 0.2 acres). In many cases, it will be appropriate to divide the site into zones of severity (e.g. lightly, moderately and heavily affected); several samples should be collected in each zone. Field indicators should also be measured in similar tundra types in the surrounding area unaffected by the spill (background or reference areas) for comparison.

Field sampling points preferably should be established at nodes on the surveyed sampling grid (Tactic AM-1). Ideally, the same measurements and observations should be made at all field sampling points.

If necessary, use survey nails or other permanent markers to physically mark the sampling points and record their locations on a scaled site map (Tactic AM-1) so they can be accurately relocated in the future. If an individual sampling location is not located at a node on the grid, record a waypoint, or the distance and direction of the sample location from a grid node. Most observations of field indicators are specifically related to the tundra surface. When subsurface soil observations are necessary, dig a small test pit and examine the sidewall of the pit, or cutting out a soil sample for easier observation.

Sample datasheets for recording field indicator data are located at the end of this section.

Considerations and Limitations

- Avoid placing stakes in locations that may interfere with treatment operations.
- Water-soluble spill residues may not be visible on the tundra surface.
- Most observations or measurements of field indicators require a thawed active layer and the absence of snow cover.
- Use plywood walkways to minimize trampling of site.

Table 7. Field sample coding sheet for visual assessments of oilspills on tundra*

Parameter	Measurement or Observation
Residue thickness on ground or vegetation	• No visible residue • If sheen is present, thickness is 0.0001 millimeters (mm) • If stain is present, thickness is 0.1 mm • If coating can be scraped with an object, thickness is 1 mm • If thickness is >1 mm, measure with ruler
Residue consistency	• No visible residue • Liquid (flowing) residue • Emulsified crude oil (mousse) • Waxy, gelatinous • Hardened, crystalline, plastic, tar • Crumbly, friable • Sheen
Residue expulsion (residual hydrocarbons can be squeezed out of surface organics or soil with foot pressure)	• No expulsion • Sheen on water • Liquid droplets or thicker film • Pooling on surface • Undetermined: test not done if surface oil present
Residue color	• Silver-gray sheen • Rainbow sheen • Light orange-brown • Dark brown • Blue-black

* Field indicators for other types of residues must be developed on a case-by-case basis. Adapted from Cater and Jorgenson 1999

Table 8. Some field indicators of soil conditions*

Parameter	Measurement or Observation
Organic layer	• Measure thickness of organic layer (includes mosses and peat) • Note any discoloration • Note odor
Mineral soil layer	• Measure depth that mineral layer begins • Note any discoloration • Note odor
Mineral soil texture[a]	• Gravel (gravel, sandy gravel, silty gravel) • Sand (sand, loamy sand, gravelly sand) • Loam (silt, silt loam, sandy loam) • Clay (silty clay, silty clay loam)
Thaw depth	• Use metal probe to measure depth of active layer of soil
Water depth	• Measure depth of water above (+; surface water) or below (-) ground surface
Containment infiltration	• *Saturation*: soil pores filled with spilled substance • *Coatings*: noticeable coating on mineral or organic particles, void spaces in soil are evident, or substance does not flow out of soil matrix • *Sheen*: sheen is visible when soil squeezed but not evident on particles

* Adapted from Cater and Jorgenson 1999

[a] Classification based on Natural Resources Conservation Service, U.S. Department of Agriculture (Schoeneberger et al. 2002)

—Continued

Table 9. Some field indicators for physical or ecological damage *

Parameter	Measurement or Observation
Tundra type	• Aquatic tundra • Wet tundra • Moist tundra • Dry tundra • Bare soil
Vegetation cover (Tactic AM-6)	• Cover estimates (0 to 5%, 6 to 25%, 26 to 50%, 51 to 75%, 76 to 95%, 96 to 100%) for shrubs, graminoids (i.e., grasses and grass-like plants), mosses, and bare soil
Vegetation damage (Tactic AM-3)	• No apparent damage • Partially crushed (some stems and leaves crushed, but structure mostly intact) • Mostly crushed (stems and leaves recognizable, but mostly laying flat on ground) • Stressed (wilted, dropping leaves, or leaves discolored) • Dead • Roots exposed • 1 to 5 inches of organic layer or soil removed • >5 inches of organic layer or soil removed
Birds and mammals (use data form)	• Species and number observed at the entire site • Condition (healthy, diseased, dead) • Note whether spill residue is visible on animal • Animal dead, probably due to other causes

* Adapted from Cater and Jorgenson 1999

Equipment, Materials, and Personnel

NOTE: Generally a team of two workers measures and records observations of field indicators.

- *Ruler or measuring tape* - to measure residue on tundra surface and the depth of infiltration.
- *Metal probe* - to measure depth of thaw, water depth.
- *Shovel* - to dig small test pit to observe soil horizons.
- *Large survey nails, wooden laths, or steel "rebar" stakes* - to mark areas where field indicators were measured or observed so they can be relocated during subsequent monitoring events.
- *GPS* - to record sample point locations.
- *Standard data forms* - to record observations.

BIRDS AND MAMMALS OBSERVATIONS FORM

Site:__________________ Date:___________ Time:_________ Observer:______________________

Species	No.	Condition	Sample ID	Notes

Condition classes: **N** (present on site but no oiling observed), **L** (lightly oiled, no detrimental effects), **H** (heavily oiled, mobility impaired), **D** (dead due to oil), **O** (dead probably to other causes).
Sample ID: if animal is collected assign it an ID number.

VISUAL ASSESSMENT FORM FOR TUNDRA OIL SPILLS

Site:______________________ Date:___________ Time:__________ Observer:____________________________

Grid Location			Photo ID	Oiling (Routine)				Cleanup Method				Eco-system Type	Water Depth (cm)	Vegetation Cover Class				Damage Level
Row	Dist-ance	Zone /Cell		Depth (mm)	Consis -tency	Expul-sion	Color	1	2	3	4		(above surface)	Shrub	Gram-inoid	Moss	Bare Soil	

Cover classes: **O** (none), **1** (0-5%), **2** (6-25%), **3** (26-50%), **4** (51-75%), **5** (76-95%), **6** (96-100%)
Oil consistency classes: **L** (liquid), **E** (emulsified, mousse), **W** (waxy, gelatinous), **P** (plastic, tar), **C** (crumbly, friable), **S** (sheen)
Oil expulsion classes: **N** (none), **S** (sheen), **L** (liquid droplets or thicker film), **P** (pooling on surface), **U** (undetermined): test not done if surface oil present
Cleanup classes: **N** (none), **I** (impoundment), **F** (flushing), **R** (raking), **C** (cutting), **S** (swabbing, squeegiing), **O** (oil skimmers, rope mops), **V** (vacuum pumping) **E** (excavation), **B** (burning), **H** (heating)
Ecosystem classes: **A** (aquatic), **W** (wet tundtra), **M** (moist tundra), **D** (dry tundra, **S** (bare soil, fill), **U** (undetermined)
Damage level: **0** (none), **1** (veg. partially crushed), **2** (veg. mostly crushed), **3** (veg. partially removed), **4** (veg. mostly removed), **5** (veg. all removed, some mosses present), **6** (veg. totally removed, 0-3 cm soil removed), **7** (3-10 cm of soil or moss mat removed), **8** (>10 cm of soil removed).

OIL INFILTRATION SURVEY FORM

Grid Location			Photo ID	Stratigraphy								Water	Oil Infiltration		
Row	Dist-ance	Zone/ Cell		Organic Layer	Mineral Layer 1			Mineral Layer 2			Thaw	Depth (cm)	Satur-ation	Coated Matrix	Sheen/ Film
				Depth (cm)	Text-ure	Top Depth	Bottom Depth	Text-ure	Top Depth	Botttom Depth	Depth (cm)	+above -below	Depth (cm)	Depth (cm)	Depth (cm)

Organic Depth includes fibric, hemic, and sapric horizons
Soil Texture: **C** (clay, silty clay, sandy clay), **L** (loam, sandy loam, silt loam, silt), **S** (sand, loamy sand, gravelly sand), **G** (gravel, sandy gravel)

Preventing Damage from Clean-up Activities

AM-3

The goal of this tactic is to help responders stop clean-up activities before too much tundra damage occurs. There is no precise definition of too much damage, however, due to site-specific differences that determine the treatment goals and selection of tactics. Thus, making the key decision during a clean-up response when the risk of physical damage from continued clean-up activity does, or does not, outweigh the benefits of recovering additional spill residuals will depend on many factors.

When field indicators (Tactic AM-2) are used to monitor clean-up effectiveness and tundra damage, responders have access to the most recent information for using the decision trees to guide the clean-up (Tactic P-1). Guidelines are presented here to help determine when clean-up activities should stop. The guidelines rely on simple observations, but some training of observers may be necessary to provide accurate information. For example, damage to soil is often readily visible but disturbance to vegetation often is more difficult to determine, especially in winter. The short growing season in the Arctic often means that a meaningful assessment of vegetation recovery may not be possible until 3–5 years after a spill.

The three most likely forms of damage to result from a spill clean-up are the compression of the organic mat, the tearing of belowground plant materials (e.g., roots and rhizomes), and the removal of vegetation and soil. Damage is less likely to occur when soils are frozen, but accurately assessing tundra damage often is not possible until summer. Soil compression is dependent on the depth to which the soil is frozen, the soil type, the amount of water in the soil, as well as the weight of equipment, the number of passes of people or equipment over a specific area. Soils that are wet, or that were frozen when wet, have pore spaces filled with water (or ice), and are less susceptible to compression and shearing forces than drier soils that have air voids. In general, wet and moist tundra will be less susceptible than dry tundra to compression and shearing forces.

In winter, the first indication that tundra disturbance is possible is the incorporation of dead plant leaves (e.g., plant litter) into the snow pack, which indicates the snow pack is no longer thick enough to provide a protective layer to the tundra surface.

According to the Alaska Department of Natural Resources (DNR), vegetation damage is defined as any visible mechanical alteration of plant anatomy such as broken or abraded branches of shrubs and scuffed or crushed tussocks, while soil damage is defined as any visible depression or displacement of soil resulting in a defined track. Tables 10 and 11 provide additional information that can be used as an overall guideline to assess six levels (from negligible to severe) of physical damage to the spill site (see also Tactic AM-2).

When assessing the level of damage, it is important to compare the spill site with adjacent undisturbed tundra of the same type. For example, undisturbed dry tundra may naturally have areas of exposed soil. This ranking system is intended to be rapid, thus the estimates of cover are subjective and different from the quantitative method used in Tactic AM-6. To rapidly assess the level of damage, an observer visually estimates the proportion of an area (e.g., a treatment cell) according to the damage variables. This rapid assessment method is most useful for describing large differences.

Considerations and Limitations

- If soil samples are collected to assess the depth of penetration by contaminants, the water content and bulk density of the soil also should be estimated to determine the likelihood of soil compression.

Equipment, Materials, and Personnel

- *Grid system* - for sampling (Tactic AM-1).
- *Sample containers, drying oven, and scale* - for calculating water content and bulk density.

Table 10. Classification and description of damage levels for tundra

Damage Level	Description
Negligible 0	No impact to slight scuffing of higher microsites. Disturbance not evident from the air or on air photos.
Low 1	The decrease in vegetation cover is <25% and the amount of exposed soil is <5%. Compression of standing plant litter and slight scuffing of soil is evident in wet, moist or dry tundra; tussocks or hummocks scuffed.
Moderate 2	The decrease in vegetation cover is 25–50%, and/or exposed soil is 5–15%. Compression of mosses and standing plant litter is evident in wet and moist tundra; tussocks or hummocks are crushed; portions of spill site may appear wetter than surrounding area; some tearing of vegetative mat within moist tundra along rivers and in dry tundra.
High 3	The decrease in vegetation cover is >50–75%, and/or exposed soil is >15–25%. Standing water is apparent on spill site that probably was not present before the spill; moist tundra changing to wet tundra; crushed tussocks or hummocks nearly continuous; change in vegetative composition; in moist tundra along rivers and in dry tundra, vegetation mat and ground cover substantially disrupted.
Very high 4	The decrease in vegetation cover is >75–95% and/or exposed soil is >25–90%. Ground depressions common in moist tundra. In wet tundra, thermokarst and ponding may result in a substantial area that is covered by water, especially where extensive areas of vegetation and surface soils have been churned or displaced. Dry tundra appears as barrens with only occasional patches of vegetation remaining.
Severe 5	Vegetation removal is essentially complete (>95%) and exposed soil is nearly continuous (>90%). Some colonizing plants may be present, but vegetation cover is less than 5%.

Table 11. Variables used to rank the damage level for tundra

Damage Variable	Damage Level					
	0	1	2	3	4	5
Vegetation Reduction (% cover)	0–4	5–24 or increase	25–50	51–75	76–95	>95
Vegetation Height (% of reference)	90–110	75–89 or >110	50–74	25–49	5–24	<5
Exposed Soil (% cover)	0	1–5	>5–15	>15–25	>25–90	>90
Microrelief (cm) (Depression, Compaction, Thermokarst, Excavation)	0	1–4	5–14	15–24	25–100	>100

Testing Soil and Water for Contaminants

AM-4

Figure 129. Monitoring water in the active layer

Government agencies may require periodic laboratory analysis of soil and water during treatment and rehabilitation of a spill site (Fig. 129). This tactic describes procedures for sampling and analysis to measure contaminants in tundra soil, surface water, and in supra-permafrost water (i.e., subsurface water within the active layer of thawed soil). Sampling and analysis plans must be approved by the Alaska Department of Environmental Conservation (ADEC). Select laboratory analyses by referring to regulations used by ADEC (18 AAC 75.341, 345 and 18 AAC 70.020) to establish chemical-specific screening criteria and cleanup levels for soil and groundwater. Workers must comply with Occupational Safety and Health Administration regulations, which require special training for sampling hazardous substances.

Selection of Sample Sites

To allow testing for a correlation between analytical results and field indicators, collect analytical samples at the same locations where field indicators are monitored (Tactic AM-2) whenever possible. If samples for analytical analysis are collected at new locations, field indicator data should also be collected at these locations. Avoid collecting analytical samples from a location that has been disturbed by monitoring for field indicators.

The number of locations selected for sampling, and the frequency of sampling must be approved by agencies. An intensive treatment and monitoring program may require ongoing sampling (weekly to monthly), while a less intense program may require annual monitoring. Sampling is normally performed when the soil is thawed.

Preventing Cross-Contamination

Avoid cross-contamination of samples by using proper sample-handling techniques and decontamination practices. Work in pairs with one person labeling jars and writing field notes without handling contaminated material, while the other person collects samples and handles sampling equipment. Decontaminate sampling equipment before each sampling event to ensure collection of representative samples and to prevent cross-contamination. Use a laboratory-grade detergent and preferably hot potable water to clean sample equipment. Rinse with tap water followed by multiple rinses with de-ionized water.

Soil Sampling Procedures

A typical cross-section of tundra soil has two distinct layers differentiated by color and texture (Tactic P-2). The upper horizon consists of dark organic soils, usually with dense plant roots and is often smooth in texture. The lower, mineral horizon is usually sandy or silty in texture, and the color is often lighter, or gleyed (grey and/or blue).

Collect samples separately for the upper (organic) soil horizon and the lower (mineral) horizon. Stainless steel spoons, disposable sample scoops, shovels, and hand augers may be used to collect surface/near-surface samples.

Surface soil samples must be collected from freshly uncovered soil to minimize the loss of any volatile compounds, and transferred directly from the freshly uncovered soil to the laboratory-supplied sample container. If a sample is to be collected in a test pit that has been open for longer than one hour, a minimum of 3 inches of surface soil should be removed immediately before collection.

Surface Water Sampling Procedures

Collect samples of surface water by gently immersing a clean sample bottle in the body of water. Avoid disturbing sediments in the immediate vicinity of the collection point before sample collection.

Field measurements of water quality parameters may be recorded after sample collection, including:

- Temperature
- pH
- Specific conductance (SC), which is calculated from electrical conductivity (EC)
- Dissolved oxygen
- Oxidation reduction (Redox) potential

Calibrate the instruments in the field before use.

Testing Surface Water for Salt Content during Flooding or Flushing

When treating a spill of a saline substance by flooding or flushing, use a hand-held field probe to monitor the EC of the water before and after it is applied to the tundra, to provide immediate confirmation that salts are being removed. EC values should decrease with successive flooding treatments as salts become diluted. However, when salts have penetrated into the soil, EC may increase temporarily when these salts are flushed out of the soil. If the soil is frozen, this increase may not occur until the soil thaws sufficiently to allow the salts to become mobile. Calibrate the conductivity meter before collecting data. Many conductivity probes automatically convert EC values to SC (EC standardized to 25°C) to allow comparison of measurements made at different temperatures. If necessary, manually convert EC readings to SC values. A variety of units are used for recording conductivity in water; the standard international unit is the Siemen (S). Conductivity meters usually display results in microSiemens/cm (µS/cm), or in milliSiemens (mS/cm). Another unit, the "mhos" is often used in the United States. Fortunately, 1 mhos = 1 S, and 1 µmhos/cm = 1µS/cm (see Tactic AM-5).

Procedures for Sampling Water from the Active Layer of Soil

Collecting samples of water below the tundra surface (i.e., in the active layer of thawed soil or supra-permafrost groundwater) requires the installation of monitoring wells (Fig. 129). Before each sampling event, a minimum of three to five well volumes of water should be purged from the well. This will remove any stagnant water in the well casing and ensure that the sample originates from the soil surrounding the well. Use a disposable bailer or a peristaltic pump to purge wells. Collect purged water in drums and dispose of it according to applicable regulatory guidelines.

Use a sterile, disposable bailer to collect water samples from wells. Immediately place water into sample containers and preserve as specified by the analytical laboratory.

Laboratory Analysis Plan

The type of substance spilled and the sample media dictate the analyses to be used. Laboratories will provide sample containers and specify required sample quantities. Table 12 provides examples of sampling and analysis parameters.

—Continued

Table 12. Examples of sampling and analysis parameters

Spilled Substances	Analysis	Matrix	EPA/ADEC Method	Containers (will vary with lab)	Preservation, Holding Time
Crude Oil, Diesel, Gasoline	Gasoline Range Organics (GRO)	Water	AK 101	40-ml VOA, TLS lid	HCl to pH<2, Cool to 4°C, extract and analyze in 14 days
		Soil	AK 101	4-oz Amber glass, teflon-lined septa (TLS) lid	Methanol, <25°C, extract and analyze in 28 days
	Diesel Range Organics (DRO)	Water	AK 102	2-1L Glass Amber	pH<2 (HCl), 4°±2°C, 7 days to extract, analyze <40 days
		Soil	AK 102	4-oz Amber glass, TLS lid	4°+2°C, 14 days to extract, analyze <40 days
	Residual Range Organics (RRO)	Water	No water method	--	–
		Soil	AK 103	4-oz Amber glass, TLS lid	4°+2°C, 14 days to extract, analyze <40 days
	Total Polynuclear Aromatic Hydrocarbons (PAH)	Water	610, 625, 8021 B, 8260 C	40 ml VOA, TLS lid	pH<2 (HCl), 4°+2°C/14 days
		Soil	8270, 8100, or 8310	4-oz Amber glass, TLS lid	4°+2°C/14 days or per method requirements
	Benzene, Toluene, Ethylbenzene, and Xylenes (BTEX)	Water	8260M (SIM)/602, 624	40-ml VOA, TLS lid	HCl pH<2, cool to 4°C, extract and ana-lyze in 14 days
		Soil	8260M/ 8021 B/ 6240/ AK 101	4-oz Amber glass, TLS lid	4°+2°C, extract and anlyze in 14 days or per method require-ments
Glycol		Water	8015 M, 8015 B	40-ml VOA	4°+2°C/7 days or per method requirements
		Soil	8015 M, 8015 B	4-oz jar	4°+2°C/7 days or per method requirements
Therminol		Water	8015 M, 8015 B	40-ml VOA	4°+2°C/7 days or per method requirements
		Soil	8015 M, 8015 B	4-oz jar	4°+2°C/7 days or per method requirements

Testing Soil and Water for Revegetation

AM-5

This tactic describes procedures for conducting tests on soil and water to provide information to help select tundra rehabilitation tactics. Some of the procedures and protocols are similar to those used to test soil for contaminants. Sample soils and water in affected and unaffected (i.e, reference) tundra to:

- Determine if salinity is suitable for germination and establishment of plants.
- Determine whether pH conditions are suitable for plant growth and microbial activity, and
- Determine baseline conditions that can be used to compare with conditions in the future
- Determine if tundra affected by a spill is substantially different from undisturbed tundra

Collect at least 3 to 6 soil samples from a site to account for variability. For larger sites, it may be useful to collect 3 to 6 samples from the area with the highest concentration of contaminants, and 3 to 6 samples from areas with moderate or lower contaminant concentrations. In addition, collecting 3 to 6 soil samples from a nearby unaffected area with similar vegetation and soil will allow the affected tundra are to be compared with undisturbed tundra, which may be important for selecting tundra rehabilitation tactics. For example, tundra near the coast can have naturally saline soils, indicating that salt-tolerant species may be needed to revegetate a site. Tundra soils typically have a surface organic layer overlying a mineral soil layer with very different characteristics, and these differences must be accounted for when using soil characteristics to make decisions.

Collect soil samples from a pit dug using a clean shovel. If necessary, collect samples at different depths to represent the entire active layer (surface to frozen subsurface). Segregate the organic rooting mat, which typically has a high content of plant roots and partially decomposed organic matter, from lower layers of mineral soil. Place each sample in resealable plastic bags (e.g., Ziploc® brand), or in DuPont™Tyvek® bags typically used by geologists. Label each bag with the site name, date, unique sample identification, and the initials of the person collecting the sample. Request that the soils laboratory analyze the organic soil layer separately from the mineral soil layer. Refrigerate soil samples 4 ± 2°C (36–43°F) until analysis to minimize biological activity. Soil samples should be air dried or frozen if it is not possible to keep them refrigerated before delivery to the laboratory within 14 days of being collected. If samples are air dried, ensure they are not exposed to hot temperatures.

Testing for Salinity

The salinity of soil and water is important to tundra plants because high concentrations of salts, such as sodium chloride, can interfere with the absorption of water into the plants, even when a substantial amount of water is present in the soil. Salts may also interfere with the ability of plants to absorb mineral nutrients (e.g., nitrogen and phosphorus). Electrical conductivity (EC) is used as a measure of the concentration of water-soluble salts in soil and water; high EC values indicate high salinity.

Tundra soil is considered saline if EC is greater than 4 dS/m (deciSiemens per meter) which is equivalent to 4 mmhos/cm (millimhos per cm). EC can also be measured in water bodies that may have been affected by a spill. EC in natural tundra water bodies is typically <800 µS/cm (microSiemens/centimeter) which is equivalent to 800 µmhos/cm (micromhos/centimeter). In tundra that is naturally saline (e.g., salt marshes), EC can be much higher. See Table 13 for conversion factors for the most common EC units.

The standard method used by a laboratory to express salinity is to measure EC of a saturated extract at 25°C. A soil extract is prepared by mixing a known mass of soil with a known volume of deionized water, usually at a 1:1 ratio. The laboratory procedure used to measure electrical conductivity in soil is described in Soil Survey Investigations Report

Table 13. Conversion factors for electrical conductivity units

From	To	Multiply by:
dS/m	µS/cm	1000
dS/m	mmhos/cm	1
mmhos/cm	µS/cm	1000

No. 42, Soil Survey Laboratory Methods Manual, Version 4.0, November 2004, USDA, NRCS. A similar method using a portable EC meter can be used in the field to rapidly assess soil salinity. A portable EC meter also can be used in the field to rapidly assess salinity of surface water. Because salinity is affected by temperature, field measurements of EC should be converted to specific conductance, which standardizes EC values to 25°C. EC results from a laboratory are reported at 25°C and do not need to be converted.

Field observations can also provide good evidence of salinity. Note the presence of free salt on the soil surface, the presence of bare ground when the surrounding tundra is vegetated, and the presence of salt-tolerant plant species. Using portable EC meters in the field to measure EC in soil and water is often helpful to aid in planning the location and number of samples to be collected for laboratory analysis.

Testing specifically for concentrations of sodium and chloride may be needed. Ion specific probes that are supported by portable field meters are available. Sodic soils have high concentrations of sodium and are a specific type of saline affected soil. If salinity is high and the pH is high (>8.5), the sodium adsorption ratio (SAR) should also be calculated. SAR takes into consideration that the adverse effect of sodium is moderated by the presence of calcium and magnesium ions.

Seeding or transplanting salt-tolerant plants may be appropriate for salt-affected sites if no salt-tolerant plants are growing nearby to revegetate the area (Tactic TR-9). Soil amendments (Tactic TR-13) may be appropriate if the site is too saline for any plant growth (Tables 14 and 15). Flooding (Tactic CR-7) or flushing (Tactic CR-8) also may be appropriate.

Table 14. Electrical conductivity values in tundra surface water and vegetation tolerance

Range of EC in Natural Tundra Water Bodies		Description	Vegetation Tolerance
dS/m and mmhos/cm	µS/cm		
< 0.8	< 800	Freshwater	All plants
0.8 – 2.0	800 – 2000	Brackish	Most plants (some growth limitation)
2.0 – 6.0	2000 – 6000	Saline	Some plants (growth limitation)
> 6.0	> 6000	Very saline	Salt-tolerant plants only

Table 15. Electrical conductivity ranges in soil for plants

Electrical Conductivity Ranges in Soil for Plants (multiple units presented)		Normal Range in Tundra Soil
Non salt-tolerant	Salt-tolerant	
0.3 – 4.0 mmhos/cm	4.0 – 6.0 mmhos/cm	<2 mmhos/cm
300 – 4000 µmhos/cm	4000 – 6000 µmhos/cm	< 2000 µmhos/cm
0.3 – 4.0 dS/m	4.0 – 6.0 dS/m	<2 dS/m

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Testing for pH

Use portable meters to measure pH in soil and water rapidly, and to help in the planning of the location and number of samples to be collected for laboratory analysis. Compare results to background levels near the site and to the normal range for tundra on the North Slope. If the pH in soil is above or below normal range (5.2 to 7.8) for tundra, a soil amendment may be appropriate. A pH range of 6.0 to 7.0 is optimal for availability of nutrients in soil. However, other pH values may be normal for that area. If sample results are similar to background levels, soil amendments are not necessary (Table 16).

Table 16. Normal pH in tundra

Normal pH Range in North Slope Tundra	
Soils	Water bodies
5.2 – 7.8	6.5 – 8.5

Testing for Physical and Chemical Characteristics of Soil

Testing for physical and chemical characteristics of soil can provide important information for selecting tundra rehabilitation tactics. The relative amounts of gravel, sand, silt, and clay, and the amount of organic matter are physical characteristics important to plant growth. Laboratories first separate each sample into the coarse earth (particles > 2 mm in size) and fine earth fractions (particles < 2 mm in size). Gravel typically comprises the coarse earth fraction in tundra soils. The fine earth fraction includes sand, silt, and clay. Most laboratory tests are conducted using only the fine earth fraction. The amount of organic matter in soil is important because it enhances water and nutrient holding capacity and improves soil structure. Some laboratory tests may not be possible if the sample is mostly organic matter. If the soil is analyzed for soil nutrients, the pH of the sample also should be analyzed because plants growing in soil with extremely high or low pH may not be able to absorb soil nutrients. Compare results from the affected area with undisturbed tundra to determine the relative importance of soil characteristics for vegetation recovery in the affected area (Table 17).

Considerations and Limitations

- Soil sampling is typically done when the active layer is thawed.
- If more than one plant community or soil type is found on a site, additional sampling will be required.
- Comparison of results between different soil horizons and tundra types on a site is not valid. Also, samples must be compared with background results from similar soils and plant communities, to determine the extent to which the area was affected by a spill.
- Mechanical analysis for soil samples may be necessary for backfill material imported to a site.

Equipment and Personnel

- *Shovel* (1 worker) - to collect soil samples.
- *Ziploc® or other plastic bags* (1-gallon size) or DuPont™Tyvek® bags - to store samples.
- *Labels and notebook* - for recording sample identifications bags and soil horizons.
- *Cooler and blue ice* - to store and ship samples to the soils laboratory.

Table 17. Laboratory tests for physical and chemical soil properties

Soil Property	Normal Range in Tundra Soil[a]
Physical	
Particle Size (%)	
Gravel	15[b]
Sand	18–69
Silt	15–64
Clay	10–39
Organic Matter (%)	5.7–55.5
Chemical	
pH	5.2–7.8
Salinity	
Electrical Conductivity (dS/m)	<2
Sodium Adsorption Ratio	<13[c]
Available Nutrients (mg/kg)	
Nitrogen, Ammonium	8.7–19.5
Nitrogen, Nitrate	5.5–15.2
Phosphorus	0.1–15
Exchangeable Cations (mg/kg)	
Potassium	92–349
Calcium	1399–7381
Magnesium	93–627
Sodium	15–150[b]

[a] Reference values (except where noted) from Walker (1985).
[b] Reference values from unpublished ABR data.
[c] Reference value from Brady and Weil (1996).

Monitoring Vegetation

AM-6

The health, cover, and composition of tundra vegetation are measured before and after treatment, to aid in assessing impacts and monitoring recovery of tundra affected by a spill. The effects of a spill can also be assessed by comparing vegetation in a spill area with vegetation in an area unaffected by the spill. The fastest field techniques for monitoring vegetation use visual observations of plant health, repeat photography (photo-trend plots), or the semiquantitative method of estimating plant cover in plots of a specified size (area method). The preferred method for monitoring vegetation is the point-intercept method, however, because it provides more objective data. The potential for revegetation of a site can be assessed with test plots to determine whether seeds will germinate or plants can establish and survive under certain conditions. Identification of plant species and implementing some of the monitoring techniques may require special expertise. If appropriate, consult with a plant scientist or other qualified person to develop a monitoring plan or to conduct the vegetation monitoring.

Plant Health

The health and condition of tundra plants growing on the site is evaluated qualitatively based on visual examination. Look for signs of growth, reproduction (flowers, seeds, spreading by roots) and vigor (health) using undisturbed vegetation not affected by the spill near the site as a reference. Signs of poor growing conditions, stress, or toxic effects of contaminants may include dead plants or dead leaves, discoloration such as yellow leaves, stunted plants, lack of reproduction, and slow or no growth. Remain alert to evidence of grazing by animals (e.g., torn leaves, scat, foot prints), which may have removed a significant amount of plant parts. Evaluation of the condition of plants does not require special expertise, although some training by experts in plant science may be useful to identify less obvious effects that may be important for achieving the treatment goals.

Photo-Trend Plots

Using photographs to monitor permanent plots is a popular and effective technique for monitoring the revegetation of affected tundra over successive growing seasons. This technique is most useful if the same view direction is used each time, and is dependent upon being able to relocate the plot. The corners of permanent plots can be marked with metal nails (6 to 9 inches in length) that are commonly used by surveyors, or with wooden or steel “rebar” stakes. A common method used to delineate individual plots in a photograph is to place a 1-meter-square quadrat frame made of white PVC pipe or aluminum flat-bar on the tundra (Fig. 130). A stake is then driven into the tundra soil in opposite corners to mark the location of the quadrat permanently. Prepare a map of the plot locations (Tactic AM-1) so that plots can be easily relocated over multiple years for repeat sampling. If possible, stand in the same location, and use the same camera focal length and exposure settings each time a plot is photographed. It can be very helpful to use a photo of the plot taken previously as a reference when re-taking photographs. Some photo-trend plots of experimental oil spill sites on the North Slope have been documented for over 25 years, providing valuable information about the recovery of the tundra.

Figure 130. 1-m^2 vegetation quadrat

Vegetation Cover

Vegetation cover is the vertical projection of vegetation from the ground as viewed from above. Vegetation cover is commonly estimated using either point or area methods (Bonham, 1989; NARSC, 1999).

- Point intercept methods are based on the number of “hits” on vegetation out of the total number of points measured; either the point “hits” a part of the plant (e.g., leaf or stem) or it does not (Fig. 131). The point is defined by shining the beam of a hand-held laser vertically down through the vegetation (i.e., perpendicular to the ground). The plant is hit when the light beam is visible as a red dot on a plant part. A second method is based on an observer looking past cross hairs made of thin wire (similar to a gun sight); the plant is hit when it lies beneath the cross hairs. The cross hairs are mounted in a tube or frame (i.e., a point frame) (Fig. 131). The laser and sighting tube are mounted on a steel rod that is driven into the ground to provide a stable sampling point. Similarly, the stability of a point frame is maintained by driving the four legs in each corner of the frame into the tundra. Many points must be sampled in groups along a line or within a frame to provide useful information. The percent cover of live plants is calculated as the total number of hits on live plants divided by the total number of points sampled. For example, if 50 points are measured and 10 points have “hits” on plants, then the total cover of live plants would be 20%. Tundra vegetation often has multiple layers, or canopies, which can result in a plant cover >100% when using point intercept methods.
- Area methods involve placing a quadrat (a square or circle) of known area on the ground surface, and visually estimating plant cover classes (Fig. 130). Typical examples of classes are 1–5%, 6–25%, 26–50%, 51–75%, and >75%. A 20- by 50-centimeter frame is a popular quadrat size for estimating tundra vegetation cover. Usually a number of quadrats (10–30) are evaluated at a site to reduce the bias inherent in this method. If more than one person is estimating plant cover, the observers should train together and compare estimates within the same quadrats to minimize the amount of error. Although more simple to implement than the point-intercept method, the area method is greatly affected by the biases of each observer. Thus, estimates of vegetation cover using the area method are more difficult to defend as being objective and repeatable.

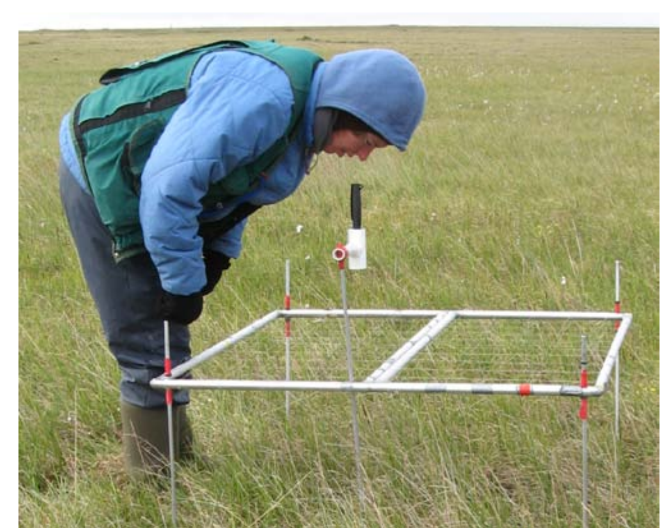

Figure 131. Laser and point-frame

Vegetation Composition

Tundra vegetation communities typically include a variety of vascular plants, including sedges, grasses, forbs (broad-leaved herbs), and dwarf or prostrate shrubs, as well as nonvascular plants such as mosses, liverworts, and lichens. The number of plant species is a useful gauge of vegetation recovery at a site when compared to similar, unaffected tundra areas. Accurate identification of plants requires some training or special expertise in plant science. An on-line information source for identification of Alaskan tundra plants is available in the PLANTS DATABASE

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(http://www.plants.usda.gov/) maintained by the U.S Department of Agriculture. Technical publications and flower guides commonly used to identify tundra plants are provided in Table 18.

Revegetation Test Plots

Before undertaking large-scale treatments such as excavation for offsite disposal (Tactic CR-13), fertilizing (Tactic TR-3 and TR-8), seeding (Tactic TR-11), or transplanting (Tactic TR-9), it may be desirable to determine if current conditions are toxic to plants. Establish plots to test seed germination or transplant survival. Seed germination and other test plots can be marked and monitored using the same methods described above.

Table 18. Sources used to identify tundra plants

Vascular Plants (Sedges, Grasses, Forbs, Shrubs)	
Flora of Alaska and Neighboring Territories	Hultén 1968
Willows of Interior Alaska	Collet 2004
Field Guide to Alaskan Wildflowers	Pratt 1989
Wetland Sedges of Alaska	Tande and Lipkin 2003
Flowering Plants of the High-Arctic	Threlkeld 1991
Wildflowers of the Yukon and Northwestern Canada, including adjacent Alaska	Trelawny 1983
Alaska Trees and Shrubs	Viereck and Little 2007
The Alaska Vegetation Classification System	Viereck et al. 1992
Nonvascular Plants (Mosses and Lichens)	
American Arctic Lichens	Thomson 1984, 1997
Wetland Indicator Bryophytes of Interior and South Central Alaska	Seppelt et al. 2006
Mosses, Lichens and Ferns of Northwest North America	Vitt et al. 1988